

## Portland State University PDXScholar

---

Civil and Environmental Engineering Master's  
Project Reports

Civil and Environmental Engineering

---

2015

# Safety at Intersections in Oregon – A Preliminary Update of Statewide Intersection Crash Rates

Daniel R. Hazel

*Portland State University*, [danhazel@live.com](mailto:danhazel@live.com)

Let us know how access to this document benefits you.

Follow this and additional works at: [http://pdxscholar.library.pdx.edu/cengin\\_gradprojects](http://pdxscholar.library.pdx.edu/cengin_gradprojects)



Part of the [Civil and Environmental Engineering Commons](#)

---

### Recommended Citation

Hazel, Daniel R., "Safety at Intersections in Oregon – A Preliminary Update of Statewide Intersection Crash Rates" (2015). *Civil and Environmental Engineering Master's Project Reports*. Paper 24.

This Project is brought to you for free and open access. It has been accepted for inclusion in Civil and Environmental Engineering Master's Project Reports by an authorized administrator of PDXScholar. For more information, please contact [pdxscholar@pdx.edu](mailto:pdxscholar@pdx.edu).

Safety at Intersections in Oregon – A Preliminary Update of Statewide Intersection Crash Rates

BY

Daniel Hazel

A research project report submitted in partial fulfillment  
of the requirement for the degree of

MASTER OF SCIENCE  
IN  
CIVIL AND ENVIRONMENTAL ENGINEERING

Project Advisor:  
Dr. Christopher M. Monsere

Portland State University  
©2015

© 2015 Daniel Robert Hazel

## **ACKNOWLEDGMENTS**

I would like to take this opportunity to thank the selection committee at Portland State University for selecting my application for admission to the Master of Science program in Civil and Environmental Engineering. Specifically, I would like to thank and acknowledge my professor, academic and research advisor Dr. Christopher M. Monsere for the support that he has provided throughout this research and my time at Portland State University.

To all those I have met throughout this journey, I thank each and every one of you for your support and encouragement. No doubt, the journey would have been a lot less interesting without you all.

I must give credit where credit is due by acknowledging the people that helped me along the way prior to my arrival at Portland State University. Dr. Roger Lindgren at the Oregon Institute of Technology provided me with an amazing learning opportunity. Had I not met Dr. Lindgren it is likely that I would not be where I am today.

Finally, I would like to take this opportunity to thank my family for their unconditional love and support throughout all of my academic endeavors. And to the incredibly beautiful, smart and supportive, Brittany Maxam, thank you for being the love of my life and always being there for me.

## **ABSTRACT**

This research aims to provide a preliminary update to statewide intersection crash rates for the state of Oregon using 2008-2013 crash data and a statewide sample of 129 intersections where two (or more) state-owned facilities intersect. Using intersections where state-owned facilities represent both the major and minor legs of the intersection allows for the maintenance of up-to-date intersection crash rates by eliminating time-intensive traffic volume data collection. Due to the frequency and severity of crashes at intersections, development of easily obtained intersection crash rates is important to assess trends and effectiveness of safety countermeasures employed at these locations in the current data year as well as over longer analysis periods.

This research also evaluates whether a recent crash report processing change within the Crash Analysis Reporting Unit of the Oregon Department of Transportation significantly increased intersection crash rates after the year 2011. As part of a special request, this research also provides fatal and incapacitating injury crash rates for a statewide sample of 500 intersections, calculated from 2003-2007 crash data.

Intersection crash rates were calculated for each of three analysis periods: 2003-2007, 2008-2010, and 2011-2013. The calculated rates were compared using statistical tests to determine if the statewide intersection crash rates had changed over time. The objective of this analysis was to detect if, over time intersection crash rates in the state of Oregon had changed significantly. Crash rates were calculated based on 2,731 crashes that were extracted from a sample of 129 intersections over an 11-year period.

To evaluate if changes that occurred with regard to crash reporting procedures within the Crash Analysis Reporting Unit manifested themselves in crash rates, statistical tests were completed to assess the rates for the analysis periods 2008-2010 and 2011-2013. The procedural

change allowed approximately 5,000 additional non-fatal crashes to be added to the yearly crash database beginning in the year 2011.

Fatal and incapacitating injury crash rates were calculated using 2003-2007 crash data for a statewide sample of 500 intersections. The Transportation Planning Analysis Unit of the Oregon Department of Transportation will use the calculated rates to flag intersections within Oregon for further safety analysis provided the crash rate at the intersection exceeds the mean or 90<sup>th</sup> percentile statewide crash rate.

Preliminary results suggest that a larger sample of intersections is required in order to provide statistically representative results. Crash rates calculated from a sample made up of only intersections where two (or more) state-owned facilities intersect did not compare to a statewide sample of intersections with facilities owned by multiple jurisdictions. Due to the limited sample size, only three of the eight intersection groups were analyzed throughout the entirety of this research. The three intersection groups analyzed were rural 3-leg stop controlled (R3ST), rural 4-leg stop controlled (R4ST), and urban 4-leg signalized (U4SG) intersections.

Results for the comparison of crash rate over time show that insufficient data were available to prove evidence of significant differences in crash rates. Larger sample sizes are required to determine if intersection crash rates in the state of Oregon have changed significantly over time.

Statistically significant results were revealed for R4ST and U4SG intersection groups, highlighting the affects of the internal crash report processing change that occurred in the year 2011. The results showed that significant increases in mean crash rates were evident when comparing the two analysis periods. More data are required to determine if the results obtained in

this preliminary analysis are cohesive in nature, spreading across all or the majority of intersection types.

Due to limited comparison data for the calculated fatal and incapacitating injury intersection crash rates for the state of Oregon, a comprehensive analysis of the resulting crash rates was not provided. The result of the calculated rates do show that on average, urban crash rates were 1.47 times greater than rural rates. Only one rural intersection group (R4ST) had fatal and incapacitating injury crash rates greater than its urban counterpart group (U4ST). The crash rates for the two intersection groups R4ST and U4ST were 3.661 and 0.321 (reported in crashes per 100 million entering vehicles), respectively.

## TABLE OF CONTENTS

<b>1.0</b>	<b>INTRODUCTION.....</b>	<b>1</b>
1.1	OBJECTIVES .....	2
1.2	ORGANIZATION .....	2
<b>2.0</b>	<b>LITERATURE REIEW .....</b>	<b>4</b>
2.1	CRASH RATES .....	4
2.1.1	SAFETY MEASURES .....	4
2.1.2	STATEWIDE INTERSECTION CRASH RATES .....	5
2.2	LITERATURE REVIEW SUMMARY .....	7
<b>3.0</b>	<b>METHODOLOGY .....</b>	<b>9</b>
3.1	DATA .....	9
3.1.1	INTERSECTION DATA .....	9
3.1.1.1	INTERSECTION SELECTION .....	10
3.1.2	TRAFFIC VOLUMES .....	12
3.1.3	CRASH DATA .....	14
3.2	DATA MATCHING .....	16
3.3	ANALYSIS TECHNIQUES .....	18
3.3.1	CRASH RATE TRENDS .....	18
3.3.2	COMPARISON OF MEANS .....	18
3.3.2.1	ANOVA .....	19
3.3.2.2	PAIRED SAMPLE T-TEST .....	19
3.4	FATAL AND INCAPACITATING INJURY CRASH RATE DEVELOPMENT .....	20
<b>4.0</b>	<b>RESULTS AND DISCUSSION .....</b>	<b>21</b>
4.1	CRASH RATES OVER TIME .....	21
4.1.1	CRASH RATE TRENDS .....	23
4.1.2	CRASH RATE TREND SUMMARY .....	26
4.1.3	ANOVA .....	27
4.1.4	ANOVA SUMMARY .....	29
4.2	CRASH DATA PROCESSING IMPACTS .....	31
4.2.1	PAIRED SAMPLE T-TEST SUMMARY .....	33
4.3	FATAL AND SERIOUS INJURY CRASH RATES .....	34
<b>5.0</b>	<b>CONCLUSION .....</b>	<b>38</b>
<b>6.0</b>	<b>REFERENCES.....</b>	<b>41</b>



## LIST OF TABLES

Table 3.1 Original Intersection Sample Size by Land-Use, # Legs, and Traffic Control.....	10
Table 3.2 State-State Intersection Sample by Land-Use, # Legs, and Traffic Control.....	11
Table 4.1 Descriptive Statistics 2008-2010 Analysis Period.....	21
Table 4.2 Descriptive Statistics 2011-2013 Analysis Period.....	22
Table 4.3 One-Way ANOVA – R3ST .....	28
Table 4.4 Tukey’s Post Hoc Analysis.....	28
Table 4.5 One-Way ANOVA – R4ST .....	29
Table 4.6 On-Way ANOVA – U4SG .....	29
Table 4.7 Repeated Measures ANOVA Test – R3ST.....	30
Table 4.8 Paired Sample T-Test – R3ST .....	32
Table 4.9 Paired Sample T-Test – R4ST .....	32
Table 4.10 Paired Sample T-Test - U4SG .....	33
Table 4.11 Statewide Intersection Crash Rates per MEV by Land Type and Traffic Control .....	35
Table 4.12 Statewide Intersection Crash Rates (F/A) per 100MEV by Land Type and Traffic Control.....	36

## LIST OF FIGURES

Figure 3.1 State-State Intersection Sample, n=129.....	12
Figure 3.2 OTMS Interface (Source: ODOT TMS).....	13
Figure 3.3 OTMS Volume Data (Source: ODOT TMS) .....	14
Figure 3.4 ArcMap Geoprocessing Buffer Tool .....	17
Figure 3.5 ArcMap Buffers, 0.01 mile and 0.05 mile.....	17
Figure 4.1 Crash Rate Paired Boxplot .....	22
Figure 4.2 Rural 3-Leg Stop-Controlled Crash Rate Trend.....	24
Figure 4.3 Rural 4-Leg Stop-Controlled Crash Rate Trend.....	25
Figure 4.4 Urban 4-Leg Signalized Crash Rate Trend .....	25

## 1.0 INTRODUCTION

Transportation safety is a major concern in the United States and is equally important in Oregon. The Oregon Department of Transportation (ODOT), like many agencies, is committed to the improvement of safety for the traveling public. Intersections are of particular interest because of the large number of crashes at these locations and how often and how severe the crashes are when they do occur (*Monseré et al., 2011*). According to ODOT, from 2005-2010, crashes occurring at or because of an intersection, on average, accounted for 15% of traffic related fatalities. This statistic translates to approximately 72 deaths per year in Oregon directly related to intersections (*ODOT, 2012*). During the same period, on average 422 fatalities occurred on Oregon roadways (*ODOT, 2015*). With the relatively large number of deaths and injuries occurring at or because of intersections, ODOT has taken a keen interest in improving safety at these locations.

One way for ODOT to determine intersection safety performance is to use crash rates. By comparing average intersection crash rates to a particular intersection, ODOT can assess the relative performance. The use of these rates requires that crash rates be calculated. A recent research project by Monseré et al. calculated intersection crash rates for different configurations, traffic control, and land use. However, because minor road traffic volumes on non-state facilities are not always available, recalculating these rates requires some effort.

This research explores the possibility of minimizing time-intensive data collection practices used previously by Monseré et al. and others but still provides useable crash rates by making the calculation using only state-owned facilities with robust annual volume counts rather than a large random sample of intersections statewide.

## **1.1 Objectives**

The primary objective of this research is to provide ODOT with crash rates for fatal (F or K) and incapacitating injury (Injury A (INJ A)) crashes using the same data as that was used by Monsere et al. In that study, the F/A rates were not calculated even though the data were available. This study also explores the impact of an internal departmental process change at ODOTs Crash Analysis Reporting (CAR) Unit that allowed approximately 5,000 additional non-fatal crash reports to be added to the crash database starting in 2011. This was accomplished by exploring how statewide intersection crash rates have changed over time. In summary, three research questions investigated during this research are as follows:

1. Have intersection crash rates in Oregon changed significantly over time?
2. Did the recent crash report processing change within ODOTs Crash Analysis Reporting Unit significantly increase intersection crash rates in Oregon?
3. What are the fatal and incapacitating injury crash rates for intersections in Oregon using 2003-2007 crash data?

## **1.2 Organization**

The remainder of this report is organized in the following chapters:

- Chapter 2: Literature Review – Brief review of pertinent studies and literature related to statewide intersection crash rates.
- Chapter 3: Methodology – Methods and data used to complete analysis of statewide crash rates.
- Chapter 4: Results and Discussion – Results of the analysis and discussion of research questions investigated.

- Chapter 5: Conclusion – Conclusions of research and recommendations for future research.

## 2.0 LITERATURE REIVEW

The review provided herein covers literature published after the year 2010. The purpose of this literature review is to identify and study previous literature on the development of statewide intersection crash rates. The review is intended to be brief because of the limited number of recently published studies.

### 2.1 Crash Rates

Published intersection crash rates are not readily available, therefore, the body of studies reviewed during this research is small.

#### 2.1.1 Safety Measures

Safety at intersections is measured in a variety of ways. Yang et al., discuss the measures used in determination of intersection safety (*Yang et al, 2014*). Crash rate, crash frequency, and KA ratio are three measures used by Yang et al. to evaluate and compare safety of intersections. Crash rate and crash frequency are the most widely used measures, with crash rate being defined by the number of crashes per year divided by the yearly traffic volume. Crash rate is typically reported in terms of crashes per million entering vehicles (MEV). The formula for calculating crash rate is as follows:

$$\text{crash rate} = \frac{\text{\# of crashes per year}}{\text{Annual Average Daily Traffic} \times 365 \div 1000000}$$

Monsere et al., state that exposure at intersections plays a key role in frequency of crashes, and that major and minor entering volumes contribute independently to crash frequency (*Monsere et al., 2011*). However, the contributions are largely unknown, but can be determined

through further analysis and statistical modeling. The formula used to calculate intersection crash rate is as follows:

$$Crash\ Rate = \frac{C * 10^6}{V * D}$$

- $C$  = number of crashes in study period
- $V$  = the sum of volumes entering from all approaches, in vehicles per day (usually AADT)
- $D$  = number of days in study period

Monsere et al. caution the use of crash rate in the assessment of an intersection's safety performance, but assure the measure is useful for quickly assessing and comparing various intersections among others (in similar volume range).

Crash frequency is simply the average number of crashes per year at an intersection. KA ratio, a measure of intersection risk is calculated as the percentage of fatal crashes (F or K) and incapacitating crashes (INJ A) out of all crashes, as defined by Yang et al.

### 2.1.2 Statewide Intersection Crash Rates

Statewide intersection crash rates are not widely available, but a few studies have been published in recent years. The two studies reviewed provide statewide intersection performance through the use of crash rate summaries in Oregon and Wisconsin. Yang et al., published a paper including a section on statewide (Wisconsin) highway intersection crash statistics.

Yang et al. looked at intersections in the two common area types of rural and urban environments using samples of 3214 and 2514 intersections, respectively. Crash rate, crash frequency, and KA ratio were calculated for the sample intersections, resulting in rural

intersections having crash rates 1.44 times greater than intersections classified as urban. The KA ratio for rural intersections was 2.46 times higher than that of urban intersections, but research revealed that urban intersections had a crash frequency 4.83 times that of the rural intersections.

According to Yang et al. these results were obtained because urban environments had higher volumes of traffic with lower speeds, leading to a higher frequency of crashes with lesser severity. Rural environments usually have lower volumes of traffic, but generally higher speeds, resulting in a lower frequency of crashes, but with higher severity (*Yang et al., 2014*).

Monsere et al., randomly sampled 500 intersections in Oregon having 3-legs and 4-legs. Intersections were only selected if minor leg volume could be obtained for at least one year in 2003-2007. Monsere et al., sampled the intersections from two land-use categories, rural and urban. The final study sample consisted of 202 rural and 298 urban intersections. Intersections were aggregated into eight configurations by land-use category (rural and urban), traffic control (stop-controlled and signalized), and intersection type (3-leg and 4-leg). Crash rate was the primary measure used by the authors to assess intersection safety and performance. Mean, median, standard deviation, coefficient of variation, and 90<sup>th</sup> percentile of the crash rates were calculated to provide more detail of the obtained rates (*Monsere et al., 2011*).

The results of statewide intersection crash rates provided by Monsere et al., show that rural intersections have lower crash rates than urban intersections with rates of 0.26-0.37 and 0.43-0.57, respectively. Crash rates reported by the authors are per million entering vehicles (MEV). The authors highlight that it's not surprising that Oregon's intersection crash rates are lower than rates published in the literature from other states because of the reporting thresholds and self-reporting style for crashes in Oregon. Monsere et al., cite these facts from Xie et al., in



their recent calibration of the Highway Safety Manual models to Oregon conditions (*Xie et al., 2011*).

Monsere et al. also discuss the applications of Oregon intersection crash rates. The authors stress that the assumption that a “perilous” intersection is one with a crash rate greater than 1.0 crashes per million entering vehicles may not be accurate. The study found only one type of intersection (rural 4-leg stop-controlled) with crash rates near 1.0. They later suggest that the 90<sup>th</sup> percentile rate would be a more appropriate “rule-of-thumb.”

Finally, Monsere et al. provide an example of a use for mean crash rates, using the idea of critical rate. The formula for critical crash rate ( $R_c$ ) is as follows:

$$R_c = R_A + K \sqrt{\frac{R_A}{M}} + \frac{1}{2M}, \text{ where}$$

$R_c$  = critical rate

$R_A$  = the average rate for similar facility

$K$  = probability constant based on desired level of significance (1.645 for 95%)

$M$  = millions of VMT or entering vehicles

Assuming that the crash rate at a particular intersection is greater than the critical rate, then likely the intersection has a crash rate greater than the average rate in Oregon for that intersection type.

## **2.2 Literature Review Summary**

The studies included in this literature review provide several measurements of safety and how to quantify and compare safety at intersections. The results of the studies reveal vastly difference intersection crash rates dependent on the state in which the study was conducted. The

rates for Oregon were less than those from Wisconsin, particularly because of the self-reporting nature of crash reporting used in Oregon. Further, rural intersection crash rates in Wisconsin were greater than urban intersection crash rates, a stark contrast to the results obtained in Oregon. It is unknown exactly why these results were obtained in Oregon and/or Wisconsin, however, mention of higher vehicular volumes in rural areas in Wisconsin could be the driving factor.

The following chapter uses aspects learned from the studies that were reviewed in the literature review to help develop the methodology for completing this research. The methodology chapter includes detailed information on data develop and data analysis.

### **3.0 METHODOLOGY**

This research borrows many aspects from the study completed by Monsere et al., including the rich intersection data sets developed during their research. Their intersection data set provided a sample of 500 intersections from all over the state of Oregon and was modified to extract only state-state intersections for the purpose of some of the comparisons made in this research. State-state intersections are defined as intersections that have at least two legs being under state jurisdiction.

To assess statewide crash rates over time, data from multiple sources was gathered, extracted, combined, and analyzed using a variety of analysis techniques. In this chapter, the data types and sources are explained in detail as well as the analysis methodology used in completion of this research.

#### **3.1 Data**

This section is split into three distinct parts including; intersection data, traffic volumes, and crash data; subsections are included for one or more parts.

##### **3.1.1 Intersection Data**

Intersection data used during this research was provided in an Access database and was used by Monsere et al. The database was compiled during the data collection phase of “*Assessment of Statewide Intersection Safety Performance*.” The database contains detailed intersection data for approximately 11,000 intersections, from which the sample of 500 intersections from throughout the state of Oregon were extracted. The intersections were selected using a mostly random stratified sampling plan. Of those 500 intersections, 202 are located in rural areas of the state, with 298 being located in urban areas. All 500 intersections are either 3-

leg or 4-leg. The sample includes intersections on the state system as well as intersections under city and/or county jurisdiction. Intersections within the sample are classified by land-use type (rural or urban), number of legs (3 or 4), and traffic control (signalized or stop-controlled on minor approach). Intersections are represented by the following abbreviations for the remainder of this research:

- Urban/Rural 3-leg signalized                      U3SG/R3SG
- Urban/Rural 3-leg stop-controlled              U3ST/R3ST
- Urban/Rural 4-leg signalized                    U4SG/R4SG
- Urban/Rural 4-leg stop-controlled            U4ST/R4ST

Table 3.1 provides the number of intersections by land-use, leg count, and traffic control used by Monsere et al. A limited number of signalized intersections are placed in rural environments, which resulted in the sample sizes for rural signalized intersections represented in the original sample to be very low. Of the 500 intersections, only 7 rural 3-leg signalized (R3SG) and 20 rural 4-leg signalized (R4SG) intersections were sampled (*Monsere et al., 2011*).

**Table 3.1 Original Intersection Sample Size by Land-Use, # Legs, and Traffic Control**

	Rural				Urban			
	3SG	3ST	4SG	4ST	3SG	3ST	4SG	4ST
Number of Intersections	7	115	20	60	55	77	106	60

### 3.1.1.1 Intersection Selection

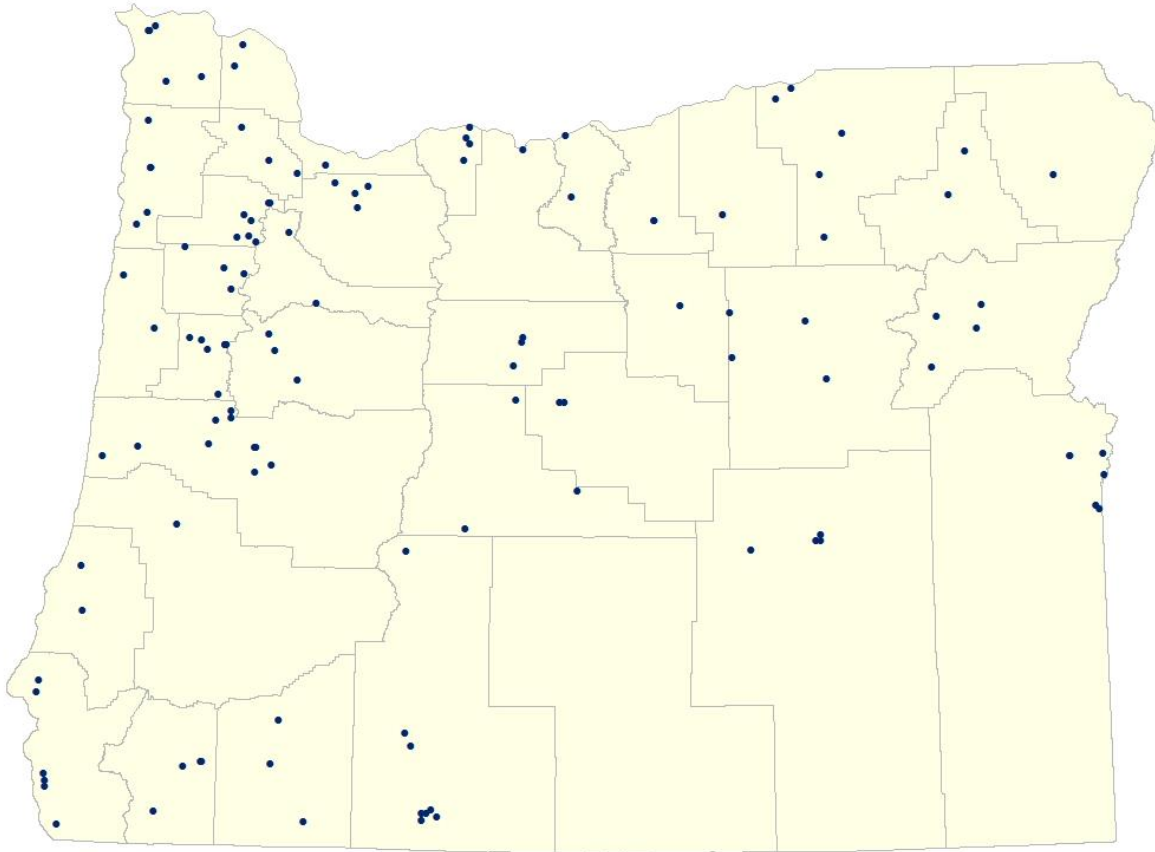
This research uses only a subset of the intersection data set from the Monsere et al. study, as discussed earlier. The sample includes only those intersections that are on the state system, where the intersecting roadway (minor approach) is another state facility. The motivation for this

sampling technique allowed traffic volumes for both the major and minor approaches to be obtained without lengthy and potentially costly data collection efforts. Two columns of the intersection databases were filtered, “JRSDCT\_TYP\_1” and “JRSDCT\_TYP\_2,” to eliminate intersections not meeting the required jurisdiction criteria. The filters for the columns were set to equal “STATE.” The resulting sample contained 136 intersections meeting the criteria described previously. Table 3.2 provides a summary of the intersections contained in the sample used during this research, however, due to issues with traffic volume data collection as is described in the following section, seven intersections were removed from the sample resulting in a final sample count of 129 state-state intersections.

**Table 3.2 State-State Intersection Sample by Land-Use, # Legs, and Traffic Control**

	<b>Rural</b>				<b>Urban</b>			
	<b>3SG</b>	<b>3ST</b>	<b>4SG</b>	<b>4ST</b>	<b>3SG</b>	<b>3ST</b>	<b>4SG</b>	<b>4ST</b>
Number of Intersections	3	53	7	23	7	2	31	3

As stated previously, the sampled intersections are distributed across the entire state of Oregon and are shown spatially in Figure 3.1. After determining the 129 intersections that would be used for the remainder of this research, traffic volumes were obtained using ODOT’s traffic volume data sources. Volume data collection is explained in detail in the following section.

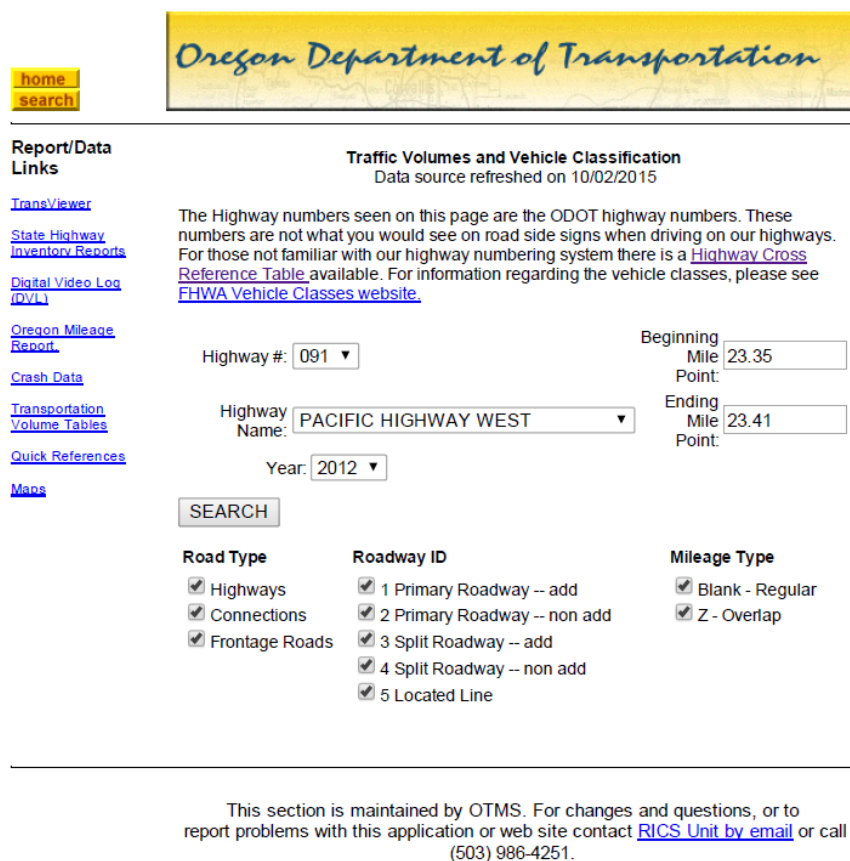


**Figure 3.1 State-State Intersection Sample, n=129**

### **3.1.2 Traffic Volumes**

Traffic volumes are a major component of this research and are required to quantify exposure and the resulting crash rates at the selected intersections. The challenge and rationale behind selecting only state-state intersections is directly related to traffic volumes. Traffic volumes, typically reported in annual average daily traffic (AADT) are not always easily available for facilities not on the state system and collection of these data would have resulted in a lengthy and costly data collection process, one which could not be undertaken during this research. ODOT's Transportation Systems Monitoring (TSM) Unit collects and processes yearly

volumes on Oregon's highways and provides historic count data dating back to the year 1986. ODOT's TSM provided the required traffic volume data for 129 of the 136 state-state intersections in the sample. Seven intersections with missing volume data were removed from the study at the end of the volume data collection process. ODOT's TSM can be assessed through yearly volume tables or through the online interface which is primarily used for vehicle classification, however, it also provides AADT data. Figure 3.2 and Figure 3.3 show ODOT's traffic volumes and vehicle classification interface ([http://highway.odot.state.or.us/cf/highwayreports/traffic\\_parms.cfm](http://highway.odot.state.or.us/cf/highwayreports/traffic_parms.cfm)). Following collection of volume data, crash data for the sample of intersections was collected. The following section provides detailed information on the process used to collect the required crash data.



**home**  
**search**

**Oregon Department of Transportation**

**Report/Data Links**  
[TransViewer](#)  
[State Highway Inventory Reports](#)  
[Digital Video Log \(DVL\)](#)  
[Oregon Mileage Report](#)  
[Crash Data](#)  
[Transportation Volume Tables](#)  
[Quick References](#)  
[Maps](#)

**Traffic Volumes and Vehicle Classification**  
 Data source refreshed on 10/02/2015

The Highway numbers seen on this page are the ODOT highway numbers. These numbers are not what you would see on road side signs when driving on our highways. For those not familiar with our highway numbering system there is a [Highway Cross Reference Table](#) available. For information regarding the vehicle classes, please see [FHWA Vehicle Classes website](#).

Highway #: 091  
 Highway Name: PACIFIC HIGHWAY WEST  
 Year: 2012

Beginning Mile Point: 23.35  
 Ending Mile Point: 23.41

**SEARCH**

Road Type	Roadway ID	Mileage Type
<input checked="" type="checkbox"/> Highways	<input checked="" type="checkbox"/> 1 Primary Roadway -- add	<input checked="" type="checkbox"/> Blank - Regular
<input checked="" type="checkbox"/> Connections	<input checked="" type="checkbox"/> 2 Primary Roadway -- non add	<input checked="" type="checkbox"/> Z - Overlap
<input checked="" type="checkbox"/> Frontage Roads	<input checked="" type="checkbox"/> 3 Split Roadway -- add	
	<input checked="" type="checkbox"/> 4 Split Roadway -- non add	
	<input checked="" type="checkbox"/> 5 Located Line	

This section is maintained by OTMS. For changes and questions, or to report problems with this application or web site contact [RICS Unit by email](#) or call (503) 986-4251.

**Figure 3.2 OTMS Interface**  
 (Source: ODOT TMS)

## Traffic Volumes and Vehicle Classification

Effective Date 12/31/2012

Highway #: 091 PACIFIC HIGHWAY WEST Hwy

Beginning Mile Point	Roadway	Mileage Type			Overlap Code	Dir Code	AADT Volume	AADT 20 YR Volume	ATR Count	Design Hour Factor	Ton Mileage Factor		
23.41	2					W	18400	21900	N	9.0	3.0		
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
Vehicle Class Percentage	0.76	60.04	31.39	0.42	2.77	0.58	0.22	0.41	1.71	1.11	0.02	0.03	0.54
Volume	140	11047	5776	77	510	107	40	75	315	204	4	6	99

ODOT Transportation System Monitoring Unit - Contact [John Barnard](#) (503) 986-4130  
10/02/2015.

Data source refreshed on

For vehicle class definitions, please see [FHWA Vehicle Classes website](#).

**Figure 3.3 OTMS Volume Data**  
(Source: ODOT TMS)

### 3.1.3 Crash Data

Crash data are available through ODOT's Crash Analysis and Report (CAR) Unit. CAR assembles and maintains crash data for crashes reported on state highways, county roadways, and city streets. The Driver and Motor Vehicle (DMV) Services Division requires citizens involved in a crash resulting in death, injury, or property damage greater than \$1,500 to file an Accident and Insurance Report within 72 hours of the crash. DMV reporting thresholds changed in 1997 from \$500 to \$1,000. Again, thresholds changed in 2004 to \$1,500. Reporting is now required for any crash where damage to any vehicle is in excess of \$1,500 and where any vehicle is towed from the crash scene as a result of the damage sustained (ODOT, 2014).

An important aspect of this research is the matching of crash data and intersection data. A definition was needed in order to determine which crashes apply to the individual intersections in



the research sample; furthermore, this research serves as a comparison to the research conducted by Monsere et al., and so the definition for matching these data sets needed to be consistent with one another. Per ODOT's CAR Unit, crashes within 50 feet of an intersection and crashes with the "intersection-related" flag checked are to be considered. In general, when a crash is entered into the database, the technician checks the intersection-related flag if the "crash is related to the movement or control of traffic through a nearby intersection (*ODOT, 2014 pg 62*).” This is typically the case for rear-end crashes at the queue of an intersection (*Monsere et al., 2011*). Crash data and intersection data were matched during this research based on the following criteria (adapted from Monsere et al.):

- Within  $\pm .01$  miles (52.8 feet) of the intersection milepost (latitude/longitude)
- Within  $\pm .05$  miles (264 feet) of the intersection milepost (latitude/longitude) and intersection-related flag checked

This research uses crashes in Oregon during the time period 2003-2013. All crash data was obtained from ODOT's CAR Unit. Crash data are available in geographic information system (GIS) geodatabases as well as Microsoft Access 2007 databases.

In 2011 ODOT's CAR Unit underwent an internal departmental process change that allowed additional non-fatal crash reports to be added to the database. The change allowed a larger number of crashes to be reported beginning in 2011. However, the increase in available crash data in the data file does not necessarily represent an increase in annual crashes (*ODOT, 2012*). Since this research analyzes crashes from the period 2003-2013, multiple comparison group timeframes (analysis periods) were used to avoid issues related to additional reporting for the years 2011-2013, and to preliminarily assess the impacts of the change in reporting. The

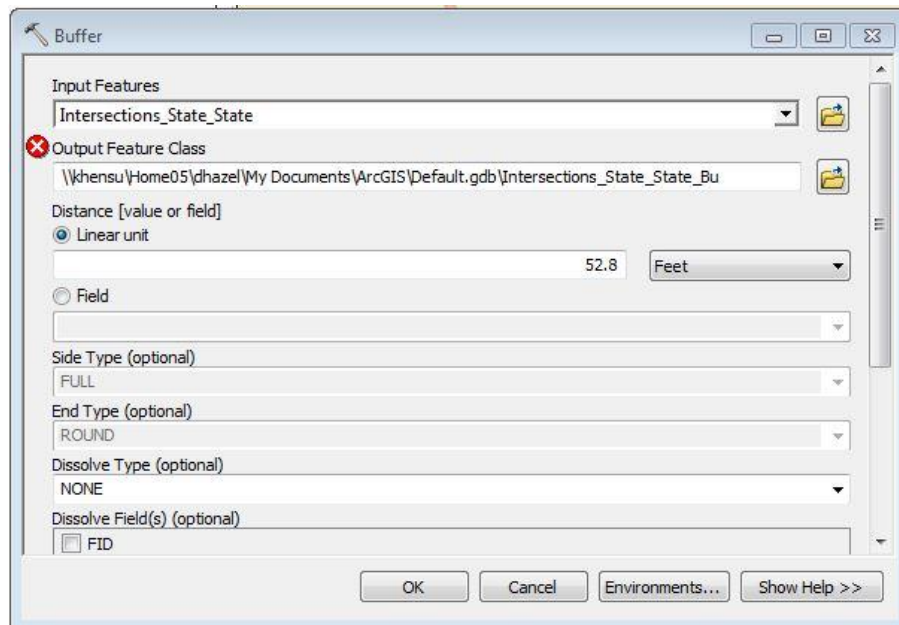
multiple data sets were matched using ArcGIS. Detailed information on the data matching process is provided in the following section.

### **3.2 Data Matching**

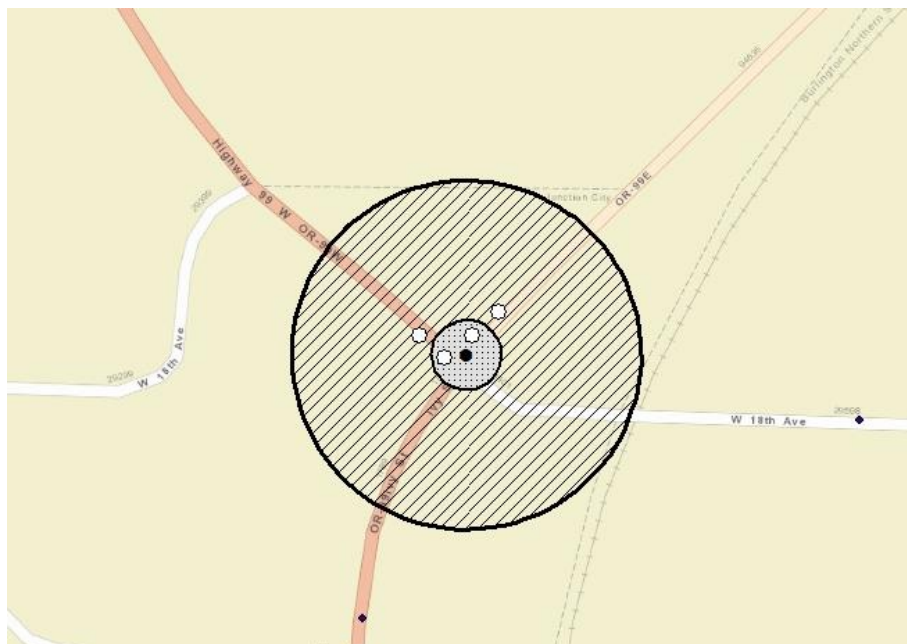
The two types of data sets that were matched during this research were the intersection and crash data sets. In order to begin the matching process, a geodatabase was developed from the intersection data and was then loaded into ArcGIS. Then the individual crash data geodatabases for 2008-2013 were loaded. In order to assign crashes to intersections based on the criteria detailed in the previous section, a buffering technique was used. The buffering technique used is a simple geoprocessing buffer of given radius from a known point (latitude and longitude of intersection). A network distance buffering process would serve the same purpose, which is similar to the process used by Yang et al., and the Wisconsin Department of Transportation. The network distance algorithm assigns crashes to an intersection based on their distance to the intersection; each crash is associated with a link and the location of the intersection is known along the link. Crashes within 0.02 mile (106 feet) of an intersection were considered to be intersection-related in their study. Although, it should be noted that distance thresholds vary between DOTs (*Yang et al., 2014*).

Two buffers were created in order to satisfy the matching of intersections and crashes. Matching selects crashes that fall within the limits of the buffer and only those crashes. Once selected, the records were exported to Excel for further processing. The 0.05 mile buffer selection included crash records where the intersection-related flag was not checked. Post-process filtering removed all crashes where the intersection-related flag was not checked. Figure 3.4 provides a visual of the ArcMap Geoprocessing Buffer Tool used to match intersections with crash records. Figure 3.5 is included and provides a visual of the two buffer configuration. The

black dot in the center represents the intersection. The white dots represent crash records within the buffers, which are the hatched areas outlined by a thick black circle. The small grey hatched circle represents the 0.01 mile buffer.



**Figure 3.4 ArcMap Geoprocessing Buffer Tool**



**Figure 3.5 ArcMap Buffers, 0.01 mile and 0.05 mile**

After exporting the matched data from ArcGIS, post-processing data manipulation was used to “clean” the data and prepare it for statistical analysis. The analysis procedures performed on the data are provided in detail in the following sections.

### **3.3 Analysis Techniques**

In order to answer the questions of this research, specific analysis techniques were used. This section provides the techniques and approaches used to evaluate the data.

#### **3.3.1 Crash Rate Trends**

The crash rate trends for each group of intersections were visualized by plotting year (x-axis) versus crash rate (y-axis). A point was plotted for each year, for each intersection. A smoothing function was used to plot the moving average of the intersection population crash rate. The plots provide a visual of the crash spread over the 11-year time period, as well as the trend of the average crash rate. The analysis serves strictly as a visual inspection of crash rates over time. The results of the crash rate trend visualization are provided and discussed in detail in Section 4.1.1. After visually comparing crash rates, the mean crash rates were statistically compared. The following three sections provide details on the processes used to compare mean crash rates.

#### **3.3.2 Comparison of Means**

Prior to statistical comparison of means, descriptive statistics were calculated for each intersection type, leg count, and land-use combination. For reference, the descriptive statistics are provided in Section **Error! Reference source not found.** The following two sections provide the analysis techniques used when comparing mean crash rates.

### **3.3.2.1 ANOVA**

One-way analysis of variance (ANOVA) was performed to assess whether crash rates for the statewide sample of intersections changed over time. Three analysis periods were analyzed, 2003-2007, 2008-2010, and 2011-2013. The split between 2010 and 2011 has been discussed in detail earlier in this research, please refer to Section 3.1.3.

The one-way ANOVA test reveals whether or not a statistically significant difference exists between two or more groups, but cannot reveal which groups differ. The results of the analysis are provided and discussed in detail in Section 4.1.3. The following section provides a detailed discussion on paired sample t-tests which are used to assess if a significant increase in crash rates were evident following the processing change that occurred in 2011.

### **3.3.2.2 Paired Sample T-Test**

Paired sample t-tests were used to assess if the crash rates changed over time when analyzing “before” and “after” conditions on the same intersection. Again, as with ANOVA, the same three analysis periods were used. In this case however, the “before” condition was assumed to be the period 2003-2007 and 2008-2010. Since, this test can be ran multiple times, “before” and “after” conditions were not constant and were dependent on the two time periods being analyzed. All combination of two analysis periods were analyzed.

The paired sample t-test calculates the difference in the crash rates for each individual intersection pair, then evaluates the mean of the differences and determines if the difference is statistically significant or not. This test has the benefit of dependence, which the 2-sample t-test does not have.

This analysis was again completed using SPSS Statistics software. The results of the paired sample t-tests are provided and discussed in detail in Section **Error! Reference source not found.** The following chapter, Chapter 4, provides results and discussion of the analyses described in the previous chapter.

### **3.4 Fatal and Incapacitating Injury Crash Rate Development**

Fatal and incapacitating injury (F/A) crash rates were calculated for the analysis period 2003-2007. Data used for this analysis were those used by Monsere et al. in the development of statewide crash rates for all crash severities.

The process used to calculate F/A crash rates involved the use of the R Statistical Programming script and crash data database used by Monsere et al. The validity of the script was checked by running it in its entirety to determine if the output matched the crash rates in the published study. After error diagnosis was complete, the crash data database was manipulated, as the original database contained crash records spread over the entire range of crash severities (KABCO severity scale). Since this analysis was used to strictly calculate F/A crash rates, all crash records in the database with crash severity (column “CRASH\_SVRTY\_DETAIL”) less than “FAT” and “INJA” were eliminated. Subsequently, the database was reduced from 4875 to 132 crash records.

After reducing the database to only F/A crashes, the database was called into R. Prior to running the script, the R code which calculates the crash rate was edited to ensure that crash rates were output in crashes per 100 million entering vehicles and not crashes per 1 million entering vehicles.

The results of the discussed analyses are provide in detail in the following section. The results have been organized in the order of the research questions, as presented in Section 1.1.

## 4.0 RESULTS AND DISCUSSION

This chapter provides the results of the analyses previously discussed and is organized to answer each of the three research questions found in Section 1.1. Each results section provides an overview of the results obtained and a discussion of those results in relation to the research questions.

### 4.1 Crash Rates Over Time

To assess whether crash rates changed over time, descriptive statistics were calculated for each analysis period; crash rates were evaluated visually over the 11-years analyzed; and a robust statistical analysis using ANOVA was completed.

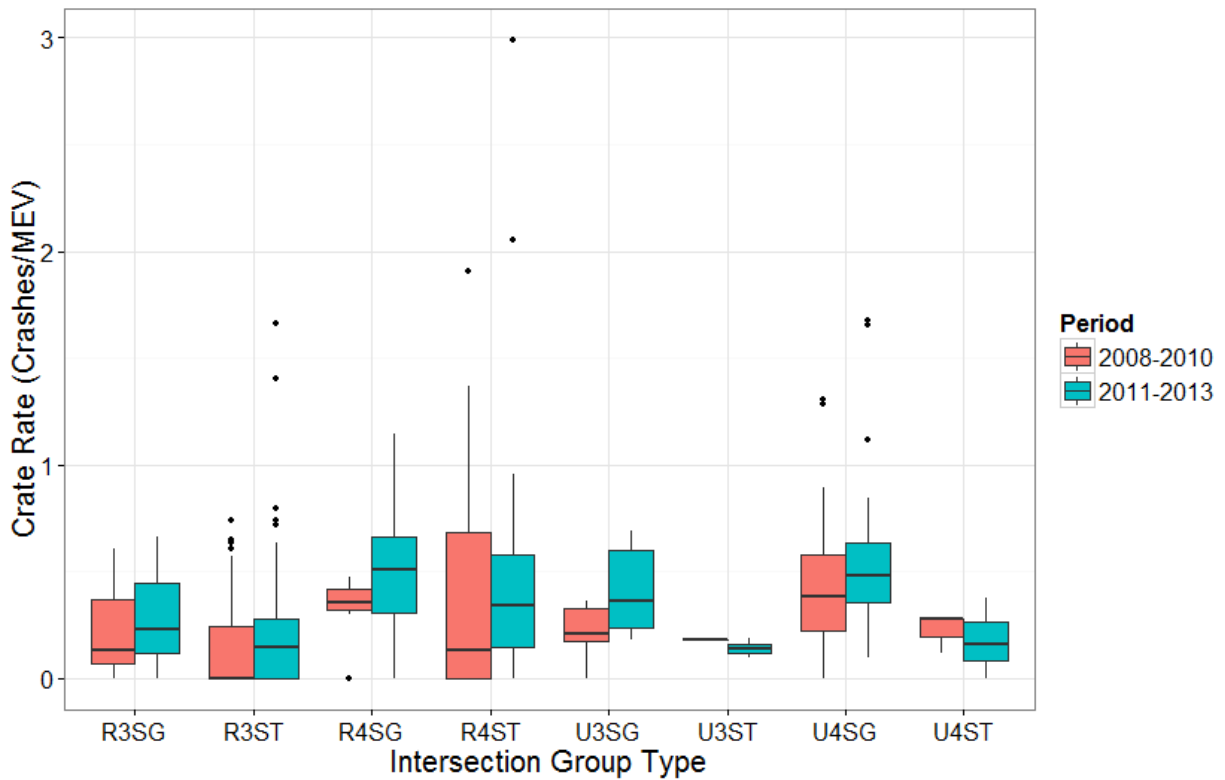
Descriptive statistics for the sample of 129 state-state intersections were calculated and are presented in Table 4.1 and Table 4.2. The tables provide descriptive statistical information for each intersection sample, including the five groups of intersections that did not undergo full statistical analysis throughout this research. Figure 4.1 provides a visual comparison of the crash rates for all intersection groups for the analysis periods of 2008-2010 and 2011-2013 using a paired boxplot.

**Table 4.1 Descriptive Statistics 2008-2010 Analysis Period**

	Rural				Urban			
	3SG	3ST	4SG	4ST	3SG	3ST	4SG	4ST
Number of Intersections	3	53	7	23	7	2	31	3
Mean Crash Rate	0.245	0.162	0.329	0.367	0.225	0.180	0.447	0.226
Median Crash Rate	0.131	0	0.358	0.133	0.210	0.180	0.386	0.276
Standard Deviation	0.317	0.223	0.157	0.514	0.130	0.009	0.326	0.094
Coefficient of Variation	1.296	1.378	0.476	1.401	0.578	0.051	0.730	0.418
90 <sup>th</sup> Percentile Rate	0.509	0.558	0.450	0.890	0.360	0.185	0.851	0.282

**Table 4.2 Descriptive Statistics 2011-2013 Analysis Period**

	Rural				Urban			
	3SG	3ST	4SG	4ST	3SG	3ST	4SG	4ST
Number of Intersections	3	53	7	23	7	2	31	3
Mean Crash Rate	0.298	0.232	0.513	0.537	0.416	0.140	0.557	0.178
Median Crash Rate	0.230	0.147	0.511	0.338	0.366	0.140	0.484	0.161
Standard Deviation	0.337	0.346	0.368	0.707	0.210	0.066	0.368	0.188
Coefficient of Variation	1.132	1.493	0.718	1.316	0.506	0.470	0.661	1.052
90 <sup>th</sup> Percentile Rate	0.576	0.630	0.898	0.951	0.636	0.177	0.846	0.331



**Figure 4.1 Crash Rate Paired Boxplot**



The tables provide statistical information such as the number of intersections in each intersection type and land-use combination, mean crash rate, median crash rate, standard deviation, coefficient of variation, and 90<sup>th</sup> percentile crash rate. Each of these statistics provide a level of insight into the crash rates for each group of intersections.

The most notable trend that is seen when comparing the tables is the mean crash rates for all intersection type and land-use combinations, except for U3ST and U4ST, increased between 2008-2010 and 2011-2013. This trend can also be visualized in Figure 4.1.

The following section provides insight into crash rates over time using plots of year versus crash rate. The plots allow crash rates to be visually inspected over the 11-year analysis timeframe. The plots also provide the moving average of the crash rates at each year and the spread of the individual intersection crash rates.

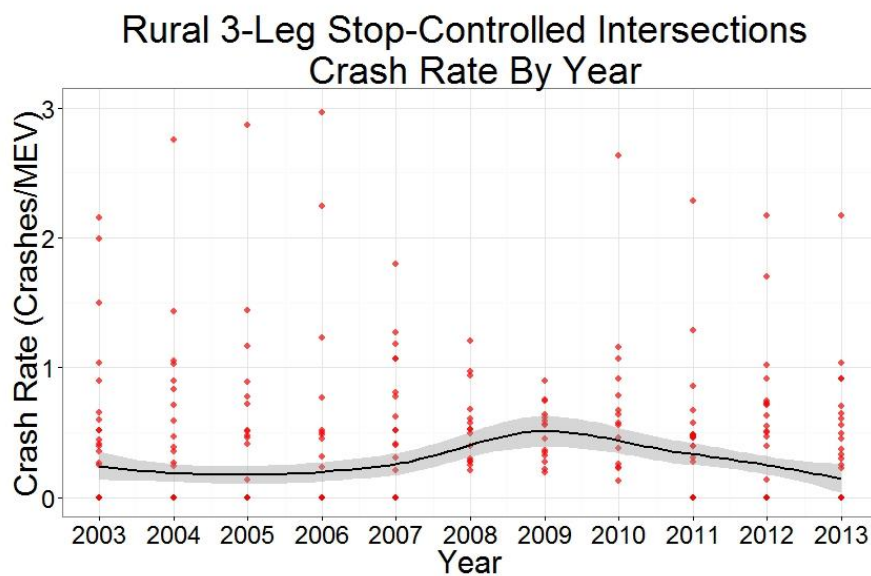
#### **4.1.1 Crash Rate Trends**

Although not the most “robust” safety performance measure, visually inspecting the trends of crash rates for each intersection type and land-use combination provides insight into the characteristics of the statewide intersection population (relative to the specific intersection type and land-use). Of the eight intersection type, leg count and land-use combinations available during this research, only three were selected to be analyzed throughout the entirety of the study. The decision was made on the basis of sample size. Rural 3-leg stop-controlled (R3ST), rural 4-leg stop-controlled (R4ST) and urban 4-leg signalized (U4SG) intersection groups were selected for further analysis and contain 53, 23, and 31 intersections each, respectively. The remaining intersection groups, on average, contained approximately 4 intersections each, which are too small to provide accurate statistical results. Typically, a minimum sample size of 30 ( $n=30$ )

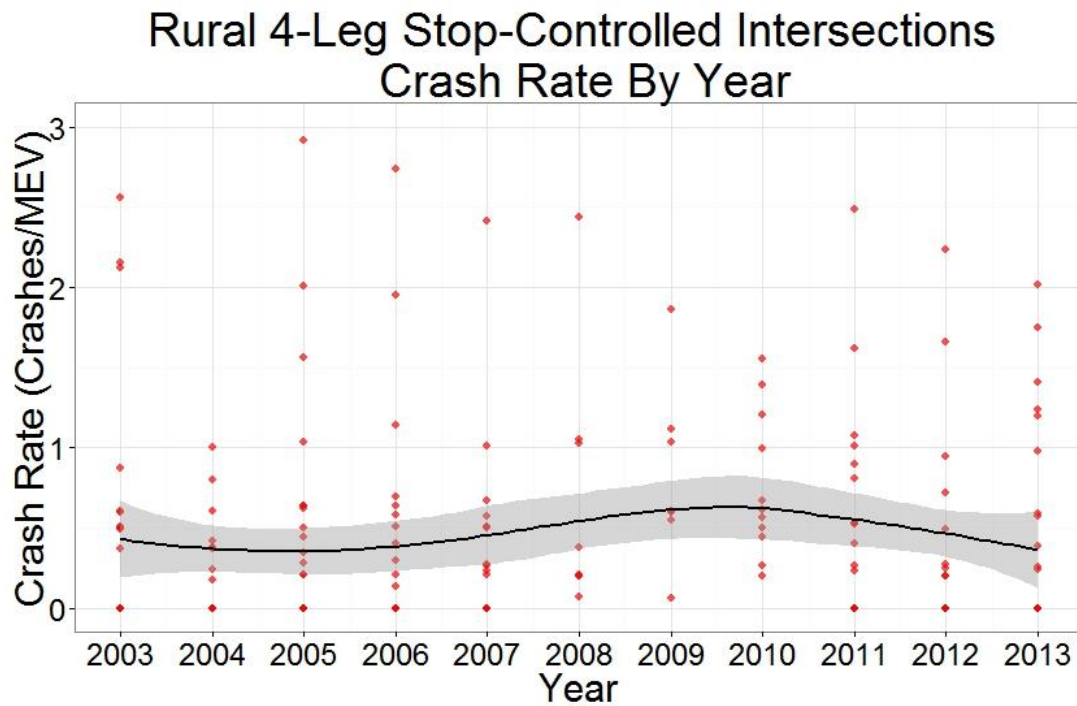
observations is needed to conduct meaningful statistical analysis, provided that non-parametric tests are not used.

As highlighted previously, plots were developed to compare year versus crash rate for the three intersection groups. The crash rate at each intersection in the group is plotted as a red dot for each of the 11-years. The smooth black line represents the moving average crash rate for the intersection sample. The grey boarder around the moving average line represents the spread of the intersection group crash rates during each year.

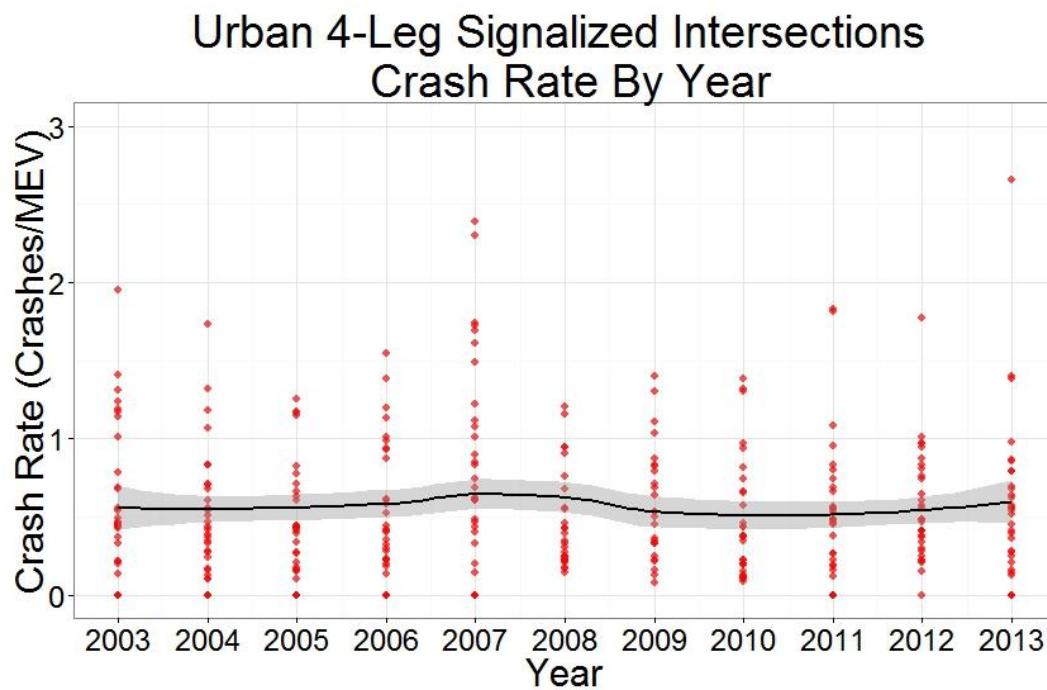
Figure 4.2, Figure 4.3, and Figure 4.3 Rural 4-Leg Stop-Controlled Crash Rate TrendFigure 4.4 provide the crash trends for R3ST, R4ST and U4SG intersections, respectively.



**Figure 4.2 Rural 3-Leg Stop-Controlled Crash Rate Trend**



**Figure 4.3 Rural 4-Leg Stop-Controlled Crash Rate Trend**



**Figure 4.4 Urban 4-Leg Signalized Crash Rate Trend**

#### 4.1.2 Crash Rate Trend Summary

Comparing the plots shown in Figure 4.2, Figure 4.3, and Figure 4.4, the variation or spread of crash rates over the 11 years analyzed is smallest for U4SG intersections. When comparing variation in crash rates between urban and rural intersections, the variation should be smaller for urban intersections, as provided by visual inspections of the former figures. Rural intersections typically have traffic volumes that are lower than urban intersections as well as lower crash frequencies. Crash frequencies for rural intersections are less than that of urban intersections as discussed by Yang et al. In Wisconsin, rural crash rates were greater than crash rates for urban locations, however, the crash frequency for urban locations was greater (*Yang et al., 2014*). Crash rates for rural intersections are greater because the occurrence of one crash will increase the crash rate to a greater extent because of relatively low traffic volumes in rural settings. On the contrary, since crash frequencies for urban settings are generally much greater and traffic volumes in urban settings are far greater than in the rural setting, an increase in one crash changes the calculated crash rate to a much lesser extent. The results of this research and the research conducted by Yang et al., are in contrast to the rates calculated by Monsere et al., in Oregon. Monsere et al., observed lower crash rates at rural intersections than at urban intersections. More data are needed to determine the exact reason for the difference in observed crash rates between this research and the research conducted by Monsere et al.

An unpublished memorandum by Eric Bonn at ODOT (TRA-03-01) from the year 1994, provides similar results to those obtained during this research. The memorandum presents crash rates for rural and urban intersections, both signalized and unsignalized.

Bonn's sample, much like the sample used during this research was made up of intersections where two state highways intersection. Bonn's research shows that crash rates are

actually greater for rural intersections, much like the results found during this research. It appears, based on the research conducted by Bonn and the results of this study, state-state only intersection samples bias crash rate results to some degree.

The following section provides results of the robust statistical analysis conducted to evaluate whether crash rates have changed significantly over time.

#### 4.1.3 ANOVA

One-way analysis of variance was used to statistically measure if crash rates across intersection type and land-use, changed significantly over the three analysis periods. The same decision rule was carried over from the crash rate trend analysis section; ANOVA was completed only for the groups classified as R3ST, R4ST and U4SG intersections.

ANOVA tests the difference among groups (analysis periods in this case) and the variation between the groups. Two hypotheses, the null hypothesis and alternative hypothesis were developed prior to testing. The null hypothesis ( $H_0$ ) assumes that all of the group means are equal to each other. The alternative hypothesis assumes that the group means are not equal, or that at least one is not equal to the others. The hypotheses are provided below in mathematical notation. The level of confidence ( $\alpha$ ) used during this research for all statistical analyses is equal to 0.05.

(Null Hypothesis)  $H_0 : \mu_{03-07} = \mu_{08-11} = \mu_{11-13}$

(Alternative Hypothesis)  $H_1 : \text{The population means are not all equal (at least one is not)}$

Table 4.3 provides the results of the one-way ANOVA for R3ST intersections. Review of the p-value (Sig. column, Table 4.3) is greater than 0.05. Since the p-value is greater than 0.05, evidence exists such that the test fails to reject the null hypothesis of all group means being equal. Therefore, the alternative hypothesis cannot be accepted.

**Table 4.3 One-Way ANOVA – R3ST**

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.282	2	0.141	1.221	0.298
Within Groups	17.998	156	0.115		
Total	18.280	158			

Although the test failed to reject the null hypothesis, Tukey's post hoc analysis is included for reference in Table 4.4. The table provides evidence that when comparing the different groups among each other, no p-value is less than 0.05.

**Table 4.4 Tukey's Post Hoc Analysis**

(I) Group		Mean Difference (I-J) Std. Error Sig.			95% Confidence Interval	
					Lower Bound	Upper Bound
03-07	08-10	0.101	0.066	0.283	-0.056	0.257
	11-13	0.030	0.066	0.889	-0.126	0.187
08-11	03-07	-0.101	0.066	0.283	-0.257	0.056
	11-13	-0.070	0.066	0.539	-0.226	0.086
11-13	03-07	-0.030	0.066	0.889	-0.187	0.126
	08-10	0.070	0.066	0.539	-0.086	0.226

Table 4.5 and Table 4.6 provide the results of one-way ANOVA testing for R4ST and U4SG intersections. As with R3ST intersections, at a 95% confidence level, the tests fail to reject the null hypothesis that the mean crash rates among the groups are different from each other. Tukey's post hoc analysis were completed for the intersection samples, but for sake of brevity, tables for the tests will not be provided. A summary of the results of the one-way ANOVA tests are provided in the following section.

**Table 4.5 One-Way ANOVA – R4ST**

	<b>Sum of Squares</b>	<b>df</b>	<b>Mean Square</b>	<b>F</b>	<b>Sig.</b>
Between Groups	0.553	2	0.277	0.666	0.517
Within Groups	27.419	66	0.415		
Total	27.972	68			

**Table 4.6 On-Way ANOVA – U4SG**

	<b>Sum of Squares</b>	<b>df</b>	<b>Mean Square</b>	<b>F</b>	<b>Sig.</b>
Between Groups	0.196	2	0.098	0.854	0.429
Within Groups	10.312	90	0.115		
Total	10.508	92			

#### 4.1.4 ANOVA Summary

Given that one-way ANOVA testing failed to reject the null hypothesis for all three intersections types, little can be said other than the findings suggest that crash rates among the three analysis periods do not seem different from one another. However, this is not saying “no statistically significant difference exists.” With the data collected, sufficient evidence does not exist to suggest that the means differ significantly.

One caveat that should be noted about using one-way ANOVA as it was in this research is the fact that the assumption of independence of observations failed to hold true. The same intersections were used for all three analysis periods in this case. Since the same observations were used, a more appropriate test would have been the one-way block ANOVA or a repeated measures ANOVA. A preliminary test was conducted on R3ST data using the method of repeated measures ANOVA. The results provided the same conclusions that were revealed using the standard one-way ANOVA. Although the assumption of independence of observations failed

to hold true, the same conclusion was found. Results of the repeated measures ANOVA are provided in Table 4.7.

**Table 4.7 Repeated Measures ANOVA Test – R3ST**

Analysis Period		Mean Difference (I-J)	Std. Error	Sig. <sup>a</sup>	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
03-07	08-10	0.101	0.066	0.409	-0.064	0.265
	11-13	0.030	0.074	1.000	-0.152	0.213
08-10	03-07	-0.101	0.066	0.409	-0.265	0.064
	11-13	-0.070	0.045	0.382	-0.182	0.042
11-13	03-07	-0.030	0.074	1.000	-0.213	0.152
	08-10	0.070	0.045	0.382	-0.042	0.182

*Based on estimated marginal means*

*a. Adjusted for multiple comparisons: Bonferroni.*

The following section provides results consistent with answering the second research question. Data were analyzed to determine if an internal crash report processing change caused statistically significant increases in intersection crash rates.



## 4.2 Crash Data Processing Impacts

To evaluate whether the internal crash data processing change that occurred within the Crash Analysis Reporting Unit of the Oregon Department of Transportation in 2011, caused statistically significant increases in crash rates, a statistical test in the form of a paired sample t-test was performed on the crash rate data. Paired sample t-tests were completed to test for significant differences in mean crash rates among all combinations of two analysis periods.

The null hypothesis ( $H_0$ ) of the paired sample t-test was that the mean of the groups' differences are equal to the hypothesized mean of the differences. The alternative hypothesis ( $H_1$ ) used in this research was that the means of the differences are not equal. The hypotheses are provided below in mathematical notation. The level of confidence ( $\alpha$ ) used during this test is equal to 0.05.

(Null Hypothesis)  $H_0 : \mu_d = \mu_0$

(Alternative Hypothesis)  $H_1 : \mu_d \neq \mu_0$

The results of the paired sample t-tests are provided in

Table 4.8, Table 4.9, and Table 4.10. For the sample of R3ST intersections, the test failed to reject the null hypothesis for all analysis-pair combinations. The data does not present enough evidence to show statistically significant differences in mean crash rates between the analysis periods, when comparison of matched intersections are considered.

**Table 4.8 Paired Sample T-Test – R3ST**

		Paired Differences							Sig. (2-tailed)
		95% Confidence Interval of the Difference					t	df	
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	03-07 - 08-10	0.100	0.415	0.0570	-0.014	0.215	1.764	52	0.084
Pair 2	08-10 - 11-13	-0.070	0.370	0.051	-0.172	0.032	-1.379	52	0.174
Pair 3	03-07 - 11-13	0.030	0.482	0.0662	-0.102	0.163	0.460	52	0.647

The results shown in Table 4.9 reveal statistically significant ( $p = 0.021$ ) differences in mean crash rates for R4ST intersections when considering the analysis periods 2008-2010 and 2011-2013.

**Table 4.9 Paired Sample T-Test – R4ST**

		Paired Differences							
		95% Confidence Interval of the Difference					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	03-07 - 08-10	0.205	0.499	0.104	-0.011	0.421	1.968	22	0.062
Pair 2	08-10 - 11-13	-0.170	0.329	0.069	-0.313	-0.028	-2.481	22	0.021
Pair 3	03-07 - 11-13	0.034	0.486	0.101	-0.176	0.245	0.340	22	0.737

Table 4.10 provides the results of the paired sample t-test conducted for U4SG intersections. The test failed to reject the null hypothesis for two of the three pairings. However, statistically significant ( $p = 0.017$ ) differences exist in mean crash rates when considering the 2008-2010 and 2011-2013 analysis periods. Increases in mean crash rates were seen from the analysis periods 2008-2010 and 2011-2013 as well as 2003-2007 and 2011-2013, however, increases were not statistically significant between 2003-2007 and 2011-2013.

**Table 4.10 Paired Sample T-Test - U4SG**

		Paired Differences						Sig. (2-tailed)	
		95% Confidence Interval of the Difference				t	df		
		Mean	Std. Deviation	Std. Error Mean	Lower				Upper
Pair 1	03-07 - 08-10	0.076	0.227	0.041	-0.008	0.159	1.858	30	0.073
Pair 2	08-10 - 11-13	-0.110	0.242	0.043	-0.198	-0.021	-2.522	30	0.017
Pair 3	03-07 - 11-13	-0.034	0.245	0.044	-0.123	0.056	-0.769	30	0.448

#### 4.2.1 Paired Sample T-Test Summary

The use of paired sample t-tests in this research allowed the comparison of crash rates at intersections over time and evaluates the significance of any observed changes that may have occurred. Also, paired sample t-tests provided evidence that the internal departmental process change that occurred in 2011 at ODOT's CAR Unit that allowed additional non-fatal crash reports to be added to the database, may have had a statistically significant impact on the reported mean crash rates at certain types of intersections. This statement assumes that the safety performance of the facilities have not changed over time (as evidenced by the rate). If the performance is unchanged, then the rate should remain constant (more or less exposure would

produce more or less crashes). However, it is known that safety performance is not always linear and that performance functions would be a more robust analysis method for these data. Of the three intersection types evaluated, two intersection types (R4ST and U4SG) had statistically significant increases in crash rates between the analysis periods of 2008-2010 and 2011-2013. For one intersection type (R3ST), sufficient evidence did not exist to prove that a statistically significant difference existed between any of the analysis periods.

The final section included in this chapter provides fatal and incapacitating injury crash rates for 2003-2007 crash data. Detailed information is included in the section detailing the process used to calculate the crash rates for fatal and incapacitating injury crashes only.

### **4.3 Fatal and Serious Injury Crash Rates**

This section provides statewide fatal (K or F) and incapacitating injury (injury A (INJ A)) crash rates using crash data from 2003-2007. Data used in this section are the same as used by Monsere et al., in the development of statewide intersection crash rates for all crash severities.

Development of statewide F and INJ A or F/A crash rates required access to, and unrestricted use of the original crash data and intersection databases. To eliminate error when calculating F/A crash rates, the database was filtered to eliminate crashes with coded severities less than INJ A. Eliminating all crash severities less than INJ A resulted in a sample of 132 total crashes. The database prior to filtering out lesser severity crashes contained 4,875 total crashes.

After manipulation of the existing database was completed, the R script used by Monsere et al. was edited to account for the change in the reported crash rate units. Crash rates, when reported for all severities, are typically reported in crashes per million entering vehicles (MEV), whereas, crash rates for F/A crashes are reported in crashes per 100 million entering vehicles. The formula for calculating F/A crash rates is as follows:

$$Crash\ Rate = \frac{C * 10^8}{V * D}$$

- $C$  = number of crashes in study period
- $V$  = the sum of volumes entering from all approaches, in vehicles per day (usually AADT)
- $D$  = number of days in study period

The published statewide crash rates for crashes of all severities are provided Table 4.11.

Again, crash rates for all crash severities are reported in crashes per million entering vehicles.

Table 4.12 provides crash rates for F/A crashes only and are reported in crashes per 100 million entering vehicles.

**Table 4.11 Statewide Intersection Crash Rates per MEV by Land Type and Traffic Control**

	Rural				Urban			
	3SG	3ST	4SG	4ST	3SG	3ST	4SG	4ST
Number of Intersections	7	115	20	60	55	77	106	60
<b>Mean Crash Rate</b>	<b>0.226</b>	<b>0.196</b>	<b>0.324</b>	<b>0.434</b>	<b>0.275</b>	<b>0.131</b>	<b>0.477</b>	<b>0.198</b>
Median Crash Rate	0.163	0.092	0.320	0.267	0.252	0.105	0.420	0.145
Standard Deviation	0.185	0.314	0.223	0.534	0.155	0.121	0.273	0.176
Coefficient of Variation	0.819	1.602	0.688	1.230	0.564	0.924	0.572	0.889
<b>90<sup>th</sup> Percentile Rate</b>	<b>0.464</b>	<b>0.475</b>	<b>0.579</b>	<b>1.080</b>	<b>0.509</b>	<b>0.293</b>	<b>0.860</b>	<b>0.408</b>

*Source: (Monsere et al., 2011)*

**Table 4.12 Statewide Intersection Crash Rates (F/A) per 100MEV by Land Type and Traffic Control**

	Rural				Urban			
	3SG	3ST	4SG	4ST	3SG	3ST	4SG	4ST
Number of Intersections	7	115	20	60	55	77	106	60
Number of Crashes	2	9	2	23	18	13	61	4
<b>Mean Crash Rate</b>	<b>0.608</b>	<b>0.428</b>	<b>0.327</b>	<b>3.661</b>	<b>0.723</b>	<b>0.482</b>	<b>1.136</b>	<b>0.321</b>
Median Crash Rate	0	0	0	0	0	0	0	0
Standard Deviation	1.609	1.821	1.009	9.567	1.812	1.382	1.699	1.308
Coefficient of Variation	2.646	4.251	3.081	2.613	2.506	2.866	1.496	4.078
<b>90<sup>th</sup> Percentile Rate</b>	<b>1.703</b>	<b>0</b>	<b>0.314</b>	<b>8.526</b>	<b>2.064</b>	<b>1.932</b>	<b>3.863</b>	<b>0</b>

From review of Table 4.12, all median crash rates and two of the 90<sup>th</sup> percentile crash rates are equal to zero. These values are not in error, but rather occur because a large percentage of the sample intersections had F/A crash frequencies equal to zero. For sake of brevity, the process for calculating these two statistical measures will not be discussed further. Table 4.12 also provides the number of crashes used for calculating F/A crash rates. The majority of the intersection groups had small numbers of F/A crashes, with only two intersection groups (R4ST and U4SG) with samples containing 20 or more crashes. During the period 2003-2007, a fatal or incapacitating injury crash occurred on average, at less than 25% of the sampled intersections.

Drawing comparisons of the crash rates provided in Table 4.12 to other crash rates is difficult due to a lack of previously published data for intersection crash rates in the state of Oregon. The majority of crash rates provided herein are not surprising and are similar in scale to the rates calculated for all crash severities (taking into account the difference in reported units). The calculated crash rate for two of the eight intersection groups were surprising. R4ST and U4SG intersections had crash rates above 1.0 crashes per 100 million entering vehicles. Although, the calculated crash rates for these two intersection groups seem excessively higher in

comparison, the vehicular volumes and/or speeds at these types of intersections are likely higher than at the other intersection groups in this study. Increasing exposure (volume), combined with higher speeds plays a key role in the occurrence of higher severity crashes.

## **5.0 CONCLUSION**

This research evaluated crash rates at a sample of 129 intersections where two (or more) state-owned facilities intersect, during three analysis periods: 2003-2007, 2008-2010, and 2011-2013. Intersection and crash data were matched to associate the crash data from each year of the analysis periods to the sampled intersections to obtain intersection crash rates for each analysis period. Data were gathered from multiple sources and matched using ArcGIS software. After matching the data, spreadsheet applications as well as statistical computing software were used to complete the analyses and crash rate calculations.

This research resulted in a preliminary update to statewide intersection crash rates using a method that almost entirely eliminated the need for costly, time-intensive data collection. The approach developed during this study for calculating intersection crash rates limits the amount of research required to gather volume data and can be completed yearly by state DOTs. This method has the possibility of providing crash rate statistics in almost real-time and potentially providing ODOT with the most up-to-date information at all times.

Preliminary results for statewide intersection crash rates at three specific land-use-traffic control-intersection types (R3ST, R4ST, U4SG) show that insufficient data were available to prove evidence of significant differences in crash rates among the three periods analyzed. A larger sample of intersections is required to prove whether crash rates for intersections in Oregon have changed significantly over time.

Assessment of the crash report processing change at the Crash Analysis Reporting Unit of the Oregon Department of Transportation in 2011 revealed significant increases in crash rates at R4ST and U4SG intersections. The processing change allowed approximately 5,000 additional non-fatal crashes to be added to the yearly crash databases. Increases in crash rates at these



intersections are likely not the result of actual increased crash frequencies, but rather a result of 5,000 additional crashes being added to the yearly databases after 2011. This statement assumes that the safety performance of the facilities have not changed over time (as evidenced by the rate).

The final analysis completed during this research calculated fatal and incapacitating injury crash rates for a statewide sample of 500 intersections using crash data from 2003-2007. The intersection sample and crash data were used to calculate intersection crash rates for the state of Oregon in 2011 by Monsere et al. In that study, fatal and incapacity injury crash rates were not calculated even though the data were available to do so. The crash rates resulting from this study allow the Transportation Planning Analysis Unit of the Oregon Department of Transportation to evaluate intersections and flag those intersections with crash rates higher than the mean or 90<sup>th</sup> percentile statewide crash rate, based on the category of intersection being evaluated.

Fatal and incapacitating injury crash rates were calculated from a sample of 132 crashes during the time period 2003-2007. On average, these higher severity crashes occurred at less than 25% of the sample intersections. Two intersection groups had unexpectedly high crash rates in excess of 1.0 crashes per 100 million entering vehicles. U4SG and R4ST intersection groups had crash rates of 1.136 and 3.661 crashes per 100 million entering vehicles, respectively. However, comparison of the calculated rates is difficult because of limited published data with respect to fatal and incapacitating injury crash rates at intersections.

Even though state facilities tend to represent the upper end of the spectrum for volumes, the Oregon statewide sample used in this research spread the expanse of traffic volumes that would be expected from a statewide sample. However, further research should be completed

using a larger sample of state-state intersections. Additionally, the distribution of volumes at the sampled intersections should be examined to verify that it is approximately normal.

The recommendations derived from this research suggest that additional research needs to be conducted using a larger sample of intersections, where state-owned facilities represent both the major and minor legs of the intersection. Furthermore, more statistical tests should be performed to assess crash rates over time. In particular, time series analysis would be beneficial. Time series analysis would be able to highlight changes in land-use adjacent to the intersections, among others. The major limiting factor of this research was with respect to temporal resources and the lack of an exhaustive sample of state-state intersections within Oregon.

## 6.0 REFERENCES

- Monsere, Christopher M., Todd Johnson, Karen Dixon, Jianfei Zheng, and Ida Van Schalkwyk. Assessment of Statewide Intersection Safety Performance. No. FHWA-OR-RD-18. 2011.
- Oregon Department of Transportation. Transportation Data Section. Crash Analysis and Reporting Unit. 2011 Oregon Traffic Crash Summary. 2012
- Oregon Department of Transportation. Traffic-Roadway Section (TRS). Overview. 2012
- Oregon Department of Transportation. Transportation Data Section. Crash Analysis and Reporting Unit. Statewide Crash Data System motor vehicle Traffic crash analysis and code manual. 2014.
- Oregon Department of Transportation. Transportation Development Division. Transportation Data Section. Crash Analysis and Reporting Unit. Crash Summaries. 2015
- Xie, Fei, Kristie Gladhill, Karen Dixon, and Christopher Monsere. "Calibration of Highway Safety Manual Predictive Models for Oregon State Highways." Transportation Research Record: Journal of the Transportation Research Board 2241 (2011): 19-28.
- Yang, Fan, Steven Parker, Bin Ran, and David A. Noyce. "Automated Statewide Highway Intersection Safety Data Collection and Evaluation Strategy." In Transportation Research Board 93rd Annual Meeting, no. 14-4212. 2014.